An Improved Jaya Algorithm and Its Scope for Optimization in Communications Engineering

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Abstract This paper proposes an improved version of Jaya algorithm for optimization. The effectiveness of the proposed version is demonstrated by solving standard benchmark functions taken from the literature. The scope of applications of the proposed algorithm in communications engineering is also presented.

Keywords Optimization · Jaya algorithm · Information and communications engineering

1 Introduction

Nowadays, the field of optimization algorithms is congested with a number of research papers appearing every month proposing 'new' or 'novel' algorithms mimicking some physical, biological, or any phenomenon or event that occurs in this universe. There is no limit to the imagination of the 'researchers' who are proposing these 'new' or 'novel' optimization algorithms. Every researcher claims that his or her algorithm is the best one and it outperforms all other existing algorithms. These 'researchers' carefully 'manage' their 'new' or 'novel' algorithms to show better results than the other algorithms. The concerns of the real optimization problems of the industrial world are addressed only by a very few researchers. The characteristics of the optimization algorithms which the users generally look for include simplicity, less complexity, ability to solve the single as well as multi-objective problems, robustness, etc. However, many 'new' or 'novel' optimization algorithms claim that they possess these characteristics, in actual practice, these claims are not found valid.

Jaya algorithm is having the characteristics which a common user looks for. It is simple yet powerful, robust, least complex, and can be used for single as well as multi-objective optimization problems. The other salient feature of Jaya algorithm is that

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the user has no burden of tuning the algorithm-specific parameters as this algorithm does not have such parameters. The convergence rate of Jaya algorithm is also better. The optimization research community is fast-adapting Jaya algorithm, and various applications can be found in different disciplines of science and engineering [1, 2].

2 Jaya Algorithm

The first step in the implementation of Jaya algorithm is to generate initial solutions. Therefore, n initial solutions are generated in random fashion by keeping in consideration the design variables' range values, i.e., upper and lower bounds. Then, every solution's variable values are updated using Eq. (1). Let the objective function be denoted with f. For demonstration, it is considered that the function is to be minimized (or maximized, according to the design problem). Say, the no. of design variables is 'nd'. best_f is used to denote the best solution and worst_f to denote the worst solution.

$$A(x+1, y, z) = A(x, y, z) + r(x, y, 1)(A(x, y, b) - |A(x, y, z)|) - r(x, y, 2)(A(x, y, w) - |A(x, y, z)|) \quad (1)$$

Among the population, the best and worst solutions are identified by their indices b and w. The indices to denote iteration, variable, and the candidate solution x, y, z. $A(x, y, z)$ mean the yth variable of zth candidate solution in xth iteration. $r(x, y, 1)$ and $r(x, y, 2)$ are the randomly generated numbers in the range of [0, 1] and act as scaling factors and to ensure good diversification. Figure 1 shows the flowchart of Jaya algorithm.

In Jaya algorithm, the value of the objective function of every candidate solution of the population is improved. Values of variables of each solution are updated by the algorithm in order to move the corresponding function value closer to the best solution. After updating variable values, comparison between the new function value and corresponding old function value. Then, only the solutions having better objective function value (lower values for minimization and higher values for maximization problems) are included in the next generation.

3 Proposed Version of Jaya Algorithm

During the last three years, few researchers had proposed certain variants of Jaya algorithm. In this paper, another variant of Jaya algorithm is proposed. This variant is expected to help in improving the speed of convergence and also in improving the search space exploration without getting entrapped in the local optima. In the original Jaya algorithm, the solutions are updated using Eq. (1). In the proposed version, Eq. (1) is modified and is given as Eq. (2).

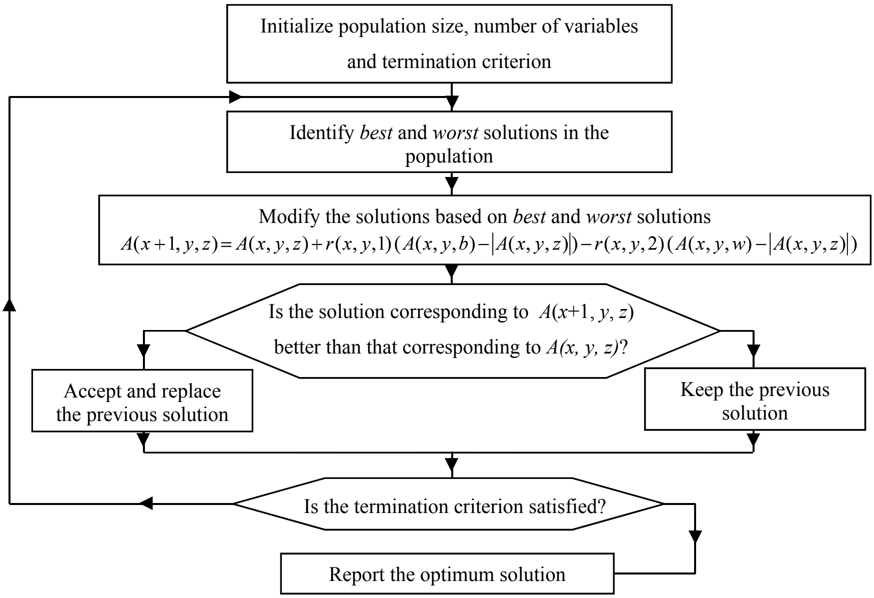

Fig. 1 Flowchart of Jaya algorithm

$$A(x+1, y, z) = A(x, y, z) + \left(\frac{1}{n}\right) r(x, y, 1) \sum (A(x, y, b) - |A(x, y, z)|) - \left(\frac{1}{n}\right) r(x, y, 2) \sum (A(x, y, w) - |A(x, y, z)|) \quad (2)$$

The only difference in the implementation of Jaya algorithm and the proposed version is that the proposed algorithm considers all the values $A(x, y, z)$ of a variable and subtracts those from the best and worst values corresponding to that variable. Then the average is considered. In Eq. (2), n is the population size.

4 Demonstration of the Proposed Version of Jaya Algorithm

The performance of the proposed version of Jaya algorithm is tested on ten unconstrained benchmark functions well documented in the optimization literature. These unconstrained functions have different characteristics like unimodality/multimodality, separability/non-separability, regularity/non-regularity, etc. The number of design variables and their ranges are different for each problem. A common experimental platform is provided by setting the maximum number of function evaluations as 500,000 for each benchmark function. The proposed version of Jaya algorithm is executed 30 times for each benchmark function.

Table 1 shows the optimization results corresponding to ten unconstrained benchmark functions. The results are shown for different population sizes n. The best values, worst values, mean values, standard deviation (SD), and the mean function evaluations (MFE) are shown in Table 1.

It may be observed from Table 1 that the proposed version of Jaya algorithm is giving good results and reaching the known optimum solutions of the corresponding benchmark functions. A comparison of these results with the results obtained by Jaya algorithm and other optimization algorithms like GA, DE, PSO, ABC given in Rao [1] reveals that the proposed version is competitive and effective.

5 Scope of Applications in Communications Engineering

The proposed version of Jaya algorithm (for that matter, original Jaya algorithm as well) has lot of scope to solve the optimization related problems of the information and communications engineering field. Some of the potential areas (not exhaustive) include the following:

- Varieties of problems in telecommunications, computer communications, and network design and routing, signal processing
- Energy consumption optimization for green device-to-device multimedia communications
- Energy efficiency optimization of device-to-device communications in 5G networks
- Outage protection for cellular-mode users in device-to-device communications
- Throughput maximization for UAV-enabled full-duplex relay system in 5G communications
- Optimization of intensities and locations of diffuse spots in indoor optical wireless communications
- Network control and rate optimization for multi-user MIMO communications
- Joint radar communications design
- Sparse transmit array design for dual-function radar communications
- System reliability optimization
- Optimization of load-balanced routing for AMI with wireless mesh networks
- Optimization of IoT cloud energy consumption
- Data mining in IoT
- Compressive sensing in IoT and monitoring applications
- Combinatorial optimization in VLSI
- Range-free localization for three-dimensional wireless sensor networks
- Task scheduling problem in the phased array radar
- Design of different types of antenna arrays
- Frequency assignment problems

Table 1 Results of application of proposed improved Jaya algorithm on unconstrained benchmark functions

S. No.	Function	Known optimum	n	Best	Worst	Mean	SD	MFE
1	Rosenbrock	0	10	0	22.191719	1.479448	5.63022	474,318.33
			20	0	0	0	0	406,028
			25	0	0	0	0	497,746
			40	0	0.000121	0.000008	0.00003	497,634
			100	0.039206	90.240443	23.304398	33.008805	491,670
2	Sphere	0	10	0	0	0	0	499,987
			20	0	0	0	0	499,953
			25	0	0	0	0	499,889
			40	0	0	0	0	499,748
			100	0	0	0	0	498,770
3	SumSquares	0	10	0	0	0	0	499,989
			20	0	0	0	0	499,946
			25	0	0	0	0	499,920
			40	0	0	0	0	499,761
			100	0	0	0	0	498,953
4	Beale	0	10	0	0	0	0	3501.33
			20	0	0	0	0	9754
			25	0	0	0	0	13,879.167
			40	0	0	0	0	25,162.67
			100	0	0	0	0	79,063
5	Easom	−1	10	−1	0	−0.966667	0.182574	2092
			20	−1	−1	−1	0	6204
			25	−1	−1	−1	0	8080
			40	−1	−1	−1	0	14,673.33
			100	−1	−1	−1	0	53,603.33

(continued)

Table 1 (continued)

S. No.	Function	Known optimum	*n*	Best	Worst	Mean	SD	MFE
6	Matyas	0	10	0	0	0	0	33,903.67
			20	0	0	0	0	83,976.67
			25	0	0	0	0	111,365
			40	0	0	0	0	199,464
			100	0	0	0	0	499,056.67
7	Colville	0	10	0	0	0	0	100,925
			20	0	0	0	0	358,473
			25	0	0	0	0	489,805
			40	0	0	0	0	487,614
			100	0.000002	0.000193	0.000032	0.000039	459,143
8	Trid 6	−50	10	−50	−50	−50	0	67,435
			20	−50	−50	−50	0	77,929.33
			25	−50	−50	−50	0	80,560
			40	−50	−50	−50	0	133,041.33
			100	−50	−50	−50	0	241,546.67
9	Trid 10	−210	10	−210	−210	−210	0	87,636.33
			20	−210	−210	−210	0	113,577.33
			25	−210	−210	−210	0	164,991.67
			40	−210	−210	−210	0	198,116
			100	−210	−210	−210	0	355,733.33
10	Zakharov	0	10	0	0	0	0	257,952.67
			20	0	0	0	0	499,846.67
			25	0	0	0	0	499,747.5
			40	0	0	0	0	499,568
			100	0	0	0	0	498,676.67

- Route optimization based on clustering
- Automatic quadratic time-frequency distribution
- Defense against emulation attacks related to security in cognitive radio networks
- Security and quality of service optimization in a real-time DBMS
- Task scheduling in heterogeneous computing systems
- Problems related to big data optimization
- Coalition formation in large-scale UAV networks
- Image encryption
- Topological optimization of interconnection networks
- Web service combination problems
- FPGA implementation to detect optimal user by cooperative spectrum sensing
- Optimization of programmable data-flow crypto processors
- Large-scale planning of dense and robust industrial wireless networks
- Congestion control in wireless sensor networks
- Cluster head selection to prolong lifetime of wireless sensor networks
- Design of band-notched UWB antennas
- Multi-user Detection for UWB communications
- Reliability and topology-based network design
- MIMO broadcast scheduling
- Training of artificial neural networks
- Optimization problems in computer communications.

The above topics are indicative, and there is a lot of scope for application of Jaya algorithm and its improved version to the optimization problems related to information and communication engineering. An application of chaotic Jaya algorithm for antenna design can be found in [3].

6 Conclusions

In this paper, the basic Jaya algorithm is modified and the performance is demonstrated on ten unconstrained benchmark functions. It is observed that the proposed version performs comparatively better and is proved to have good search ability. The implementation of the proposed version is relatively simple and easier. A selective list of potential topics in the field of communications engineering is prepared, and these topics can be addressed by the proposed version. The future scope of work includes these topics.

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